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Structure Formation and the Global 21-cm Signal in the Presence of Coulomb-like Dark Matter-Baryon Interactions

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Interactions between dark matter (DM) and baryons in which the cross section scales with relative particle velocity as $^{-4}$ has enjoyed a lot of attention in DM literature as a generalization of the popular millicharge model. This model has interesting astrophysical phenomenology and was previously proposed as a mechanism to cool down hydrogen at Cosmic Dawn and alter the global 21-cm signal. In this work, we present the first self-consistent modeling of the effect of $^{-4}$ DM–baryon scattering that accounts for the effects of interactions on structure formation, in addition to their effects on the thermal history of hydrogen. We show that □–4 scattering with cross sections needed to significantly alter the temperature of baryons also significantly suppresses and delays the growth of structure at epochs relevant for the 21-cm signal, implying that the two effects should be considered jointly. We show that in the context of the EDGES anomaly, consideration of both effects entirely eliminates millicharge as a viable model, even in absence of any other observational bounds. For the case of $^{-4}$ scattering with neutral targets, the same effects dramatically narrow the viable parameter space. These results critically inform modeling of the global 21-cm signal and structure formation in cosmologies with DM–baryon scattering, with repercussions for future and upcoming cosmological data analysis.

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